Limb lengthening with a submuscular locking plate

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Ten patients, who were unsuitable for limb lengthening over an intramedullary nail, underwent lengthening with a submuscular locking plate. Their mean age at operation was 18.5 years (11 to 40). After fixing a locking plate submuscularly on the proximal segment, an external fixator was applied to lengthen the bone after corticotomy. Lengthening was at 1 mm/day and on reaching the target length, three or four screws were placed in the plate in the distal segment and the external fixator was removed. All patients achieved the pre-operative target length at a mean of 4.0 cm (3.2 to 5.5). The mean duration of external fixation was 61.6 days (45 to 113) and the mean external fixation index was 15.1 days/cm (13.2 to 20.5), which was less than one-third of the mean healing index (48 days/cm (41.3 to 55)). There were only minor complications.

Lengthening with a submuscular locking plate can successfully permit early removal of the fixator with fewer complications and is a useful alternative in children or when nailing is difficult.

Limb lengthening by distraction osteogenesis has been widely used since it was first described by Ilizarov.¹ In an effort to reduce the complications associated with a long period of external fixation and increase patient comfort, refinements in techniques of lengthening have been developed.²⁻⁵ Lengthening over an intramedullary (IM) nail^{3,6} reduces the duration of external fixation and protects the distracted bone during the consolidation phase. The method also allows patients to regain movement faster and return to daily life earlier.^{7,8} However, IM nails are difficult to use when there is a narrow medullary canal, if the bone is deformed, in the presence of joint contracture or if the physis is open. Furthermore, IM nailing of the femur may result in osteonecrosis of the femoral head, especially in children.⁶

Submuscular fixation with a locking plate is a recent advance in the treatment of fractures.⁹ The technique has the biomechanical advantage of angular stability and it preserves the periosteal and endosteal blood supply. We describe our experience with this technique in limb lengthening.

Materials and Methods

We prospectively performed limb lengthening using an external fixator and a submuscular locking plate in ten patients. The operations were performed by a single experienced

surgeon (C-WO) between 2004 and 2007. The study was approved by the review body of our institute and conducted after obtaining informed consent from the parents or guardians of the patients.

The indications were an open physis in four cases, bony deformity in four cases, a narrow intramedullary canal in one and joint contracture in one. There were eight males and two females, with a mean age at operation of 18.5 years (11 to 40). Four of the procedures were on the femur and six on the tibia. The causes of femoral length discrepancy were neonatal hip infection in two cases, Perthes' disease in one, and epiphyseal injury of the distal femur in one. Tibial lengthening was performed on two patients who had undergone limb salvage for osteosarcoma, and one case each of clubfoot, osteomyelitis, fibular hemimelia and idiopathic tibial dysplasia. The two patients with an osteosarcoma had a previous allograft following resection of a distal femoral lesion and, because of the possibility of poor regeneration of distraction callus, tibial lengthening was undertaken as their secondary reconstruction procedure. A monolateral fixator was used in eight patients and a circular frame in two cases of tibial lengthening. One of these required correction of another deformity at a different level, and the other, who had fibular hemimelia with a

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Fig. 1a

Fig. 1b

Fig. 1c

Patient 2 – a) An 11-year-old boy had an idiopathic leg-length discrepancy due to tibial shortening of about 32 mm. b and c) A submuscular locking plate was placed laterally without involving the physal plate, and a monolateral external fixator was fixed medially to lengthen the tibia.

Fig. 2a

Fig. 2b

Fig. 2c

a) After achieving the target length, b) four screws were placed in the distal segment and the external fixator was removed. c) Six months later, the distraction callus had healed without complications.

lax knee joint, might have needed extended fixation above the knee. All cases were followed for a minimum of one year, with a mean of 25 months (13 to 58). None had previously undergone a lengthening procedure, and all had normal limb alignment with no angular or rotational deformity or joint instability. A 5.0 mm locking compression plate (Synthes, Oberdorf, Switzerland) was used for inter-

nal fixation. A standard narrow plate was used in four femurs and one tibia, and a pre-contoured proximal lateral plate in five tibiae.

Operative technique. *Tibial lengthening* (Figs 1 and 2). With the patient supine on a radiolucent table, an incision 3 cm to 4 cm long was made in the area of Gerdy's tubercle at the proximal tibia. A pre-contoured lateral plate was

Patient 8 – a) A 13-year-old boy showed femoral shortening and proximal femoral deformity due to septic arthritis of the hip. b) After insertion of a submuscular locking plate, c and d) a monolateral fixator with lengthening apparatus was introduced. e) Satisfactory lengthening was achieved.

a) After achieving the target length, the external fixator was removed and distal screws inserted. b) At one year an excellent result has been achieved.

chosen, long enough to place at least three holes distal to the planned osteotomy, taking into account the proposed amount of lengthening. After making a submuscular tunnel, the plate was inserted extra-periosteally along the lateral surface of the tibia. Four or five locking screws were inserted

proximally without damaging the physis. Through a second incision, using multiple drill holes and a handheld osteotome, metaphyseal corticotomy was performed 1 cm below the distal screw of the proximal segment. The monolateral lengthening frame, in two cases a ring fixator, was fixed to the medial side of each segment with three half pins, avoiding the plate and screws. A 3.5 mm cortical screw was then introduced to hold the distal tibiofibular joint.

Femoral lengthening (Figs 3 and 4). A narrow plate was chosen, long enough to allow the required lengthening. With the patient supine or in the lateral position, an incision 3 cm to 4 cm long was made along the lateral aspect of the greater trochanter. After making the submuscular tunnel, the plate was inserted along the lateral surface of the femur. Three or four locking screws were used to fit the plate to the proximal segment. A metaphyseal corticotomy was performed 1 cm below the distal screw. In two cases a flexible nail was inserted to stabilise the distal segment during lengthening. The monolateral frame was fixed to the lateral side of each segment with three half pins, which were carefully placed to avoid possible cross-contamination with the plate or growth arrest.

After seven to ten days, distraction was started at a rate of 1 mm/day. Partial weight-bearing was allowed and physiotherapy begun as soon as possible in order to maintain movement in adjacent joints. Frequent radiographs were obtained to monitor progress. After the desired length had been achieved patients were returned to the operating

Table I. Clinical data of limb lengthening with a submuscular locking plate

Number	Gender	Age (yrs)	Disease	Reason	Location	Ex-fix*	Target length (mm)	Percentile (%)	Duration of Ex-fix (days)	EFI† (days/cm)	HI‡	Cx
1	M	14	Clubfoot	Open physis	Tibia	Mono	34	11	45	13.2	48.5	Mild pin track infection
2	M	11	Idiopathic¶	Open physis	Tibia	Mono	32	11	46	14.4	50.0	Mild pin track infection
3	M	14	Osteosarcoma	Open physis	Tibia	Mono	47	15	62	13.2	48.3	Transient ankle stiffness
4	F	13	Fibular hemimelia	Open physis	Tibia	Ring	42	16	58	13.8	47.3	Plate failure
5	M	16	Osteosarcoma	Knee contracture	Tibia	Mono	44	14	71	16.1	47.7	Mild pin track infection
6	M	40	Osteomyelitis	Residual deformity	Tibia	Ring	55	18	113	20.5	50.0	Transient ankle stiffness
7	M	20	Post injury	Narrow medulla	Femur	Mono	32	10	49	15.3	55.0	Transient hip stiffness
8	M	13	Septic hip	Residual deformity	Femur	Mono	40	13	56	14.0	44.5	None
9	M	19	Perthes' disease	Residual deformity	Femur	Mono	33	10	45	13.6	47.9	Mild pin track infection
10	F	25	Septic hip	Residual deformity	Femur	Mono	43	12	71	16.5	41.3	Transient knee stiffness
Mean							40.2	13	61.6	15.1	48.0	

* Ex-fix, external fixator; mono, monolateral fixator; Ring, ring fixator

† EFI, external fixation index

‡ HI, healing index

¶ The cause of leg-length discrepancy is not known. The patient did not show any sign of skeletal deformity or other disease

theatre, where under fluoroscopic guidance, three bicortical screws were placed percutaneously through the plate into the distal fragment. The fixator was then removed. Casting was not used. Radiographs were taken every four weeks until the callus was fully consolidated. Mobilisation of the joints was encouraged and partial weight-bearing started immediately after removal of the fixator. When signs of bony consolidation were observed in at least three cortices on anteroposterior and lateral radiographs, patients were allowed to walk fully weight-bearing with crutches, then slowly weaned off these as tolerated.

The healing index was defined as the time between the application of the external fixator and consolidation of three cortices, divided by the length of distraction achieved. The external fixation index was defined as the time between the application of an external fixator and its removal, divided by the length achieved. Complications were classified using Paley's system.¹⁰ Problems were defined as temporary being difficulties that arose during treatment and resolved completely, and obstacles being difficulties arising during treatment which only resolved following an operation. Sequelae were defined as permanent difficulties remaining after treatment.

Results

The mean amount of lengthening achieved in the ten patients was 4.0 cm (3.2 to 5.5) which was 13% of the pre-operative bone length (10% to 18%). The mean duration of external fixation was 61.6 days (45 to 113). The mean external fixation and healing indices were 15.1 days/cm (13.2 to 20.5) and 48.1 days/cm (41.3 to 55.0), respectively (Table I).

There were nine complications in the ten patients. All had resolved by the last follow-up. There were four cases of superficial pin track infection which responded to oral antibiotics and four of joint stiffness which resolved with physiotherapy. All patients regained a full range of movement. Another patient who fell during a sports-related activity four months after removal of the external fixator presented with a fracture of the tibial distraction callus and failure of the locking plate. The proximal segment had been fixed with one unicortical and two bicortical screws, which might have given less stable fixation than in the other cases. However, the fracture healed uneventfully after re-fixation with a longer locking plate and more screws (Fig. 5).

At the most recent follow-up, all ten patients had returned to full unassisted weight-bearing, had excellent joint movements and solid union at the site of lengthening. All had maintained their pre-operative normal limb alignment without rotational or angular deformity or joint laxity.

Discussion

Although distraction osteogenesis with an external fixator is widely used for limb-length discrepancies,^{1,11-13} there are many complications related to prolonged external fixation, such as pin track infection, joint instability and stiffness, and re-fracture after removal of the fixator.^{10,13-16} Attempts have been made to reduce these complications by lengthening over an IM nail^{3,6} or with an intramedullary elongation nail.^{17,19} Lengthening over an IM nail has reduced the duration of external fixation and the rate of complications compared to the use of an external fixator only.²⁰ In our study, a submuscular locking plate also significantly reduced the duration of external fixation, as the external fixation index

Patient 4 – a) Tibial lengthening was performed in a 13-year-old girl with fibula hemimelia using a submuscular locking plate. b) After achieving 42 mm of lengthening, the distal screws were inserted. Unfortunately, c) she fell during sports activity four months post-operatively and the plate and distraction callus failed (d). Re-fixation using a longer locking plate and more screws resulted in uneventful healing.

was less than one-third of the healing index. All the patients thereby regained pre-operative joint movement, in contrast to Herzenberg et al,²¹ who found that 20% of their patients had knee flexion $< 120^\circ$ after classic Ilizarov femoral lengthening. Furthermore, our technique also helped reduce complications to less than those reported for lengthening over an IM nail.^{3,22,23}

Lengthening over an IM nail is one of the most commonly used techniques. It reduces the time needed for external fixation and protects newly formed bone,^{3,8,22} but it is difficult to apply in children because of the narrow medullary canal, an open physis and the possibility of osteonecrosis of the femoral head.^{6,8} However, using a humeral nail inserted through the greater trochanter, Gordon et al⁶ achieved femoral lengthening without osteonecrosis. Our technique allows lengthening of the femur and tibia in children without the risks of femoral head osteonecrosis and physeal injury. The method may also be useful where a nail cannot be inserted, such as in bony deformity. Whether the implant used to assist lengthening is an IM nail or a locking plate, a number of conditions must be met. Firstly, the periosteal or endosteal circulation should be protected to promote good formation of the distraction callus.^{1,17} Submuscular plating preserves the periosteum,⁹ whereas an IM nail may require reaming, which may harm the endosteal blood supply.^{3,24}

Secondly, the extra implant should not provoke complications from the pin tracks of external fixators. Lengthening over an IM nail introduces the risk of deep infection and cross-contamination, because gaps between the nails and half pins are smaller than a few millimetres. Deep infection rates between 2% and 22% have been reported with this technique.^{6,8,23,24} With a submuscular locking plate, the half-pins are further from the plate and we had no case of deep infection.

The additional implant must be strong enough to provide sufficient stability throughout bony consolidation after removal of the fixator. Intramedullary nails are considered an ideal load-sharing device,⁹ but the fixed angle stability of the locking compression plate also provides excellent stiffness.⁹

Iobst and Dahl²⁴ described a technique similar to ours in young children and applied a circular cast to protect the distraction callus. However, they encountered serious complications in five of their eight patients. We consider that stiffness resulting from their use of a short plate was the main cause. In our one serious complication in which the regenerate and the plate failed, a cast was not needed. Weak fixation of the proximal segment may have been a contributory factor. We now fix three bicortical screws into each segment and have encountered no similar failures. Another way to avoid this complication is by adding a small-diameter IM rod, as in two cases of femoral lengthening in our

series. Although this technique potentially increases the risk of infection, it may prevent fracture and angular deformity after removal of the fixator.

Drawbacks to our technique include possible limitation in the amount of lengthening compared to lengthening over an IM nail,⁶ as to maintain adequate stability, a portion of the locking plate must remain along the distal femoral segment at the conclusion of lengthening. We prefer to use as long a locking plate as possible, with at least three fixation holes remaining after achieving the target length. In the femur, this approach may be further limited since the plate is fixed on the same side as the monolateral fixator and should not make contact with the half pins; the lengthening percentages are smaller than with the Ilizarov technique.¹ The use of a ring fixator with medial half pins may overcome this limitation. When considering bending and axial stiffness, a plate is inherently inferior to an IM nail. Therefore, we prefer not to use a locking plate when an IM nail can be inserted into a medullary canal of sufficient diameter. Both methods require a second operation for removal of the implant which is a disadvantage compared to lengthening without a plate or nail.

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References

1. Ilizarov GA. The principles of the Ilizarov method. *Bull Hosp Joint Dis* 1988;48:1-11.
2. Baumgart R, Betz A, Schweiberer L. A fully implantable motorized intramedullary nail for limb lengthening and bone transport. *Clin Orthop* 1997;343:135-43.
3. Paley D, Herzenberg JE, Paremain G, Bhav A. Femoral lengthening over an intramedullary nail: a matched-case comparison with Ilizarov lengthening. *J Bone Joint Surg [Am]* 1997;79-A:1464-80.
4. Aston WJ, Calder PR, Baker D, Hartley J, Hill RA. Lengthening of the congenital short femur using the Ilizarov technique: a single-surgeon series. *J Bone Joint Surg [Br]* 2009;91-B:962-7.
5. Simpson AH, Shalaby H, Kennan G. Femoral lengthening with the Intramedullary Skeletal Kinetic Distractor. *J Bone Joint Surg [Br]* 2009;91-B:955-61.
6. Gordon JE, Goldfarb CA, Luhmann SJ, Lyons D, Schoenecker PL. Femoral lengthening over a humeral intramedullary nail in preadolescent children. *J Bone Joint Surg [Am]* 2002;84-A:930-7.
7. Kocaoglu M, Eralp L, Kilicoglu O, Burc H, Cakmak M. Complications encountered during lengthening over an intramedullary nail. *J Bone Joint Surg [Am]* 2004;86-A:2406-11.
8. Simpson AH, Cole AS, Kenwright J. Leg lengthening over an intramedullary nail. *J Bone Joint Surg [Br]* 1999;81-B:1041-5.
9. Perren SM. Evolution of the internal fixation of long bone fractures: the scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg [Br]* 2002;84-B:1093-10.
10. Paley D. Problems, obstacles, and complications of limb lengthening by the Ilizarov technique. *Clin Orthop* 1990;250:81-104.
11. Price CT, Mann JW. Experience with the Orthofix device for limb lengthening. *Orthop Clin North Am* 1991;22:651-61.
12. Stanitski DF, Shahcheraghi H, Nicker DA, Armstrong PF. Results of tibial lengthening with the Ilizarov technique. *J Pediatr Orthop* 1996;6:168-72.
13. Zarzycki D, Tesiorowski M, Zarzycka M, Kacki W, Jasiewicz B. Long-term results of lower limb lengthening by the Wagner method. *J Pediatr Orthop* 2002;22:371-4.
14. Simpson AH, Kenwright J. Fracture after distraction osteogenesis. *J Bone Joint Surg [Br]* 2000;82-B:659-65.
15. Liu T, Zhang X, Li Z, et al. Callus distraction for humeral nonunion with bone loss and limb shortening caused by chronic osteomyelitis. *J Bone Joint Surg [Br]* 2008;90-B:795-800.
16. Zhang X, Liu T, Li Z, Peng W. Reconstruction with callus distraction for nonunion with bone loss and leg shortening caused by suppurative osteomyelitis of the femur. *J Bone Joint Surg [Br]* 2007;89-B:1509-14.
17. Garcia-Cimbrelo E, Curto de la Mano A, Garcia-Rey E, Cordero J, Marti-Ciruelos R. The intramedullary elongation nail for femoral lengthening. *J Bone Joint Surg [Br]* 2002;84-B:971-7.
18. Guichet JM, Deromedis B, Donnan LT, et al. Gradual femoral lengthening with the Albizzia intramedullary nail. *J Bone Joint Surg [Am]* 2003;85-A:838-48.
19. Hankmeier S, Pape HC, Gosling T, et al. Improved comfort in lower limb lengthening with the intramedullary skeletal kinetic distractor: principles and preliminary clinical experiences. *Arch Orthop Trauma Surg* 2004;124:129-33.
20. Park HW, Yang KH, Lee KS, et al. Tibial lengthening over an intramedullary nail with use of the Ilizarov external fixator for idiopathic short stature. *J Bone Joint Surg [Am]* 2008;90-A:1970-8.
21. Herzenberg JE, Scheufele PT, Paley D, Bechtel R, Tepper S. Knee range of motion in isolated femoral lengthening. *Clin Orthop* 1994;301:49-54.
22. Song HR, Oh CW, Mattoo R, et al. Femoral lengthening over an intramedullary nail using the external fixator: risk of infection and knee problems in 22 patients with a follow-up of 2 years or more. *Acta Orthop* 2005;76:245-52.
23. Kristiansen LP, Steen H. Lengthening of the tibia over an intramedullary nail, using the Ilizarov external fixator: major complications and slow consolidation in 9 lengthenings. *Acta Orthop Scand* 1990;70:271-4.
24. Iobst CA, Dahl MT. Limb lengthening with submuscular plate stabilization: a case series and description of the technique. *J Pediatr Orthop* 2007;27:504-9.